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1354502 COMPLETE SPECIFICATION

5 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

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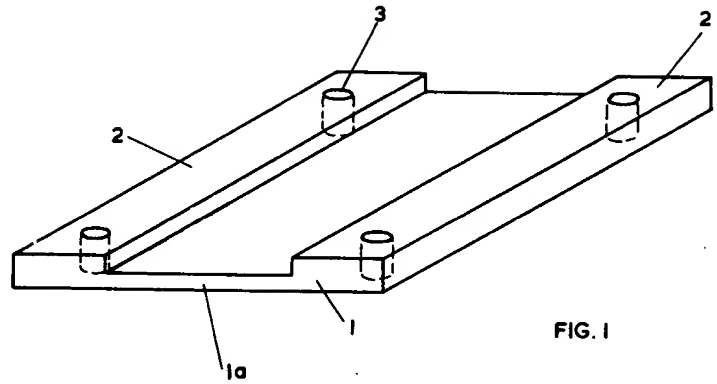


FIG. 1

FIG. 2

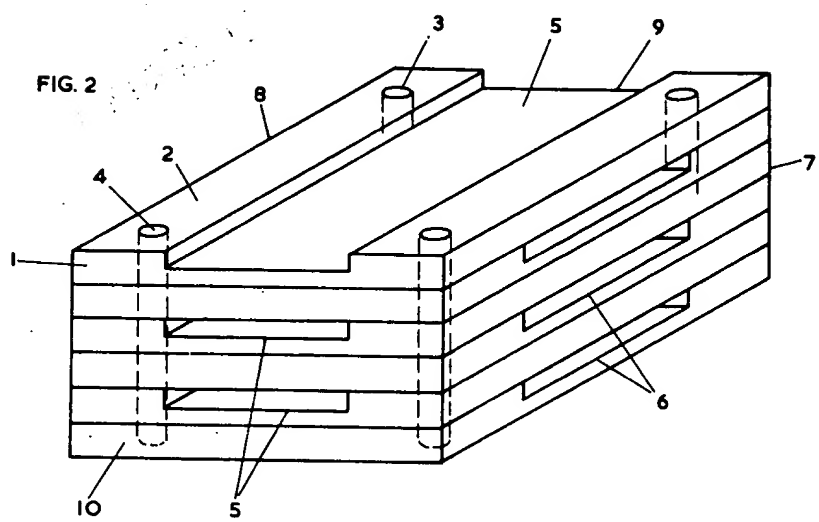


FIG. 3

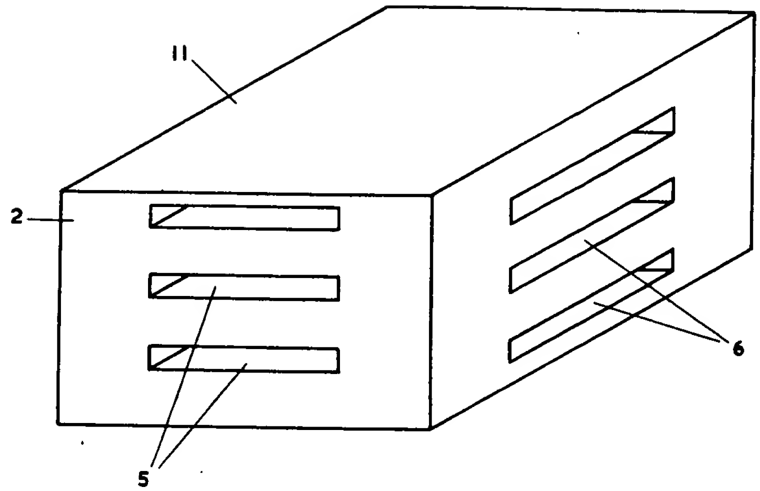
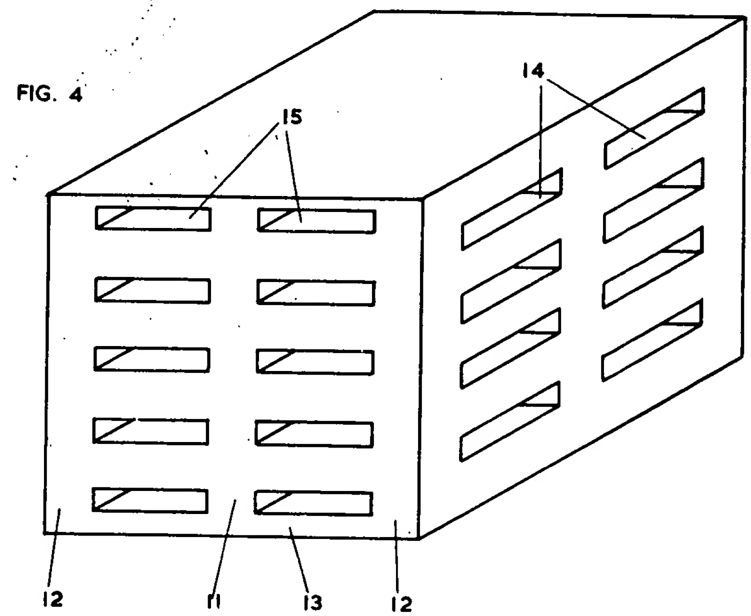


FIG. 4



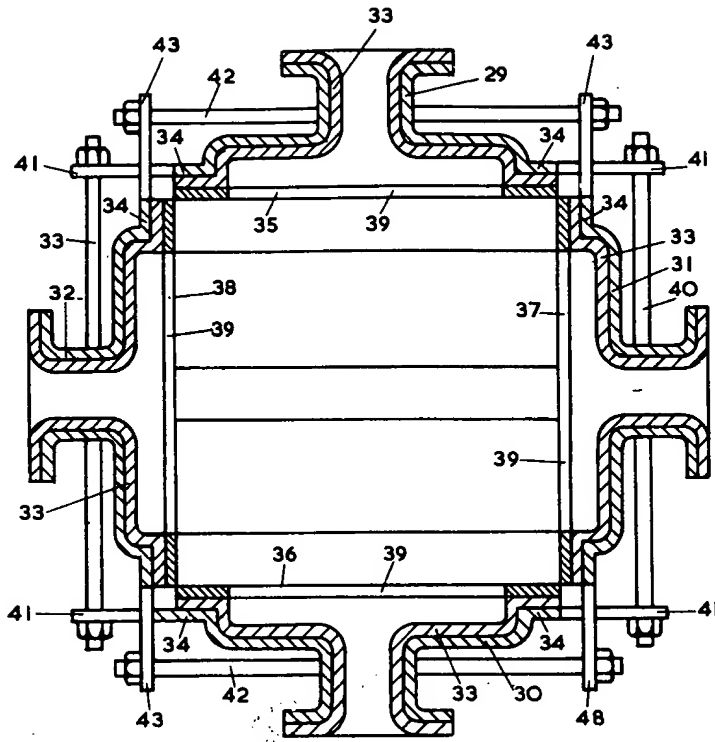

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FIG. 5

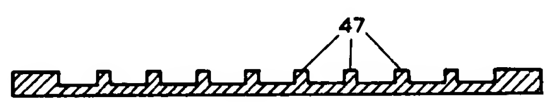
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FIG. 6

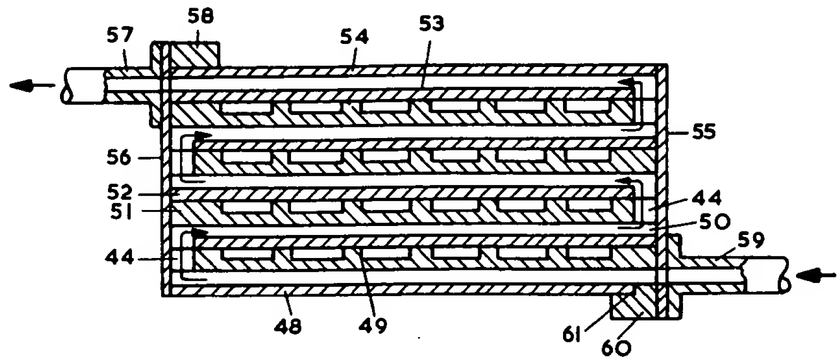
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FIG. 7

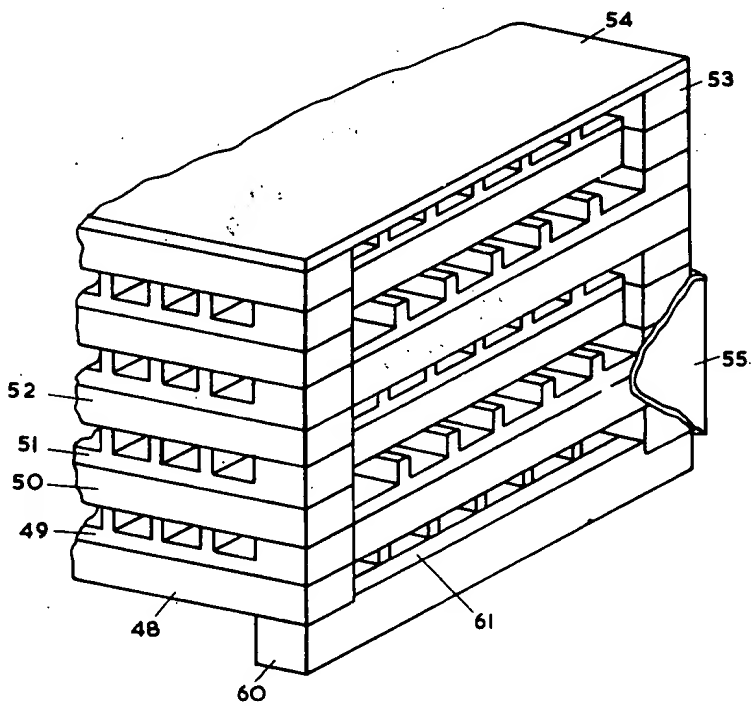
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FIG. 8

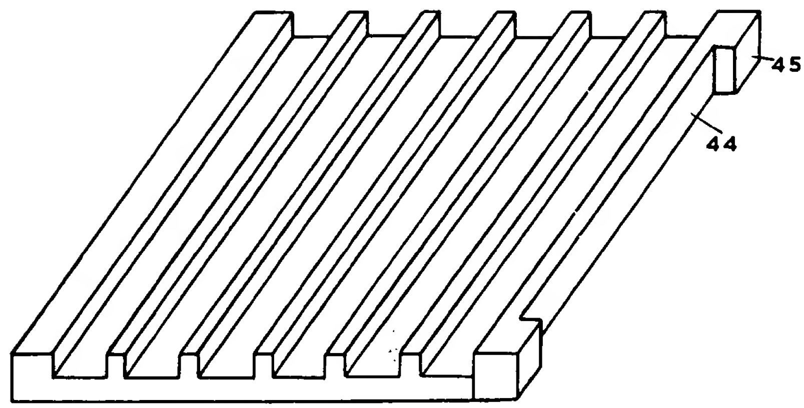

FIG. 9

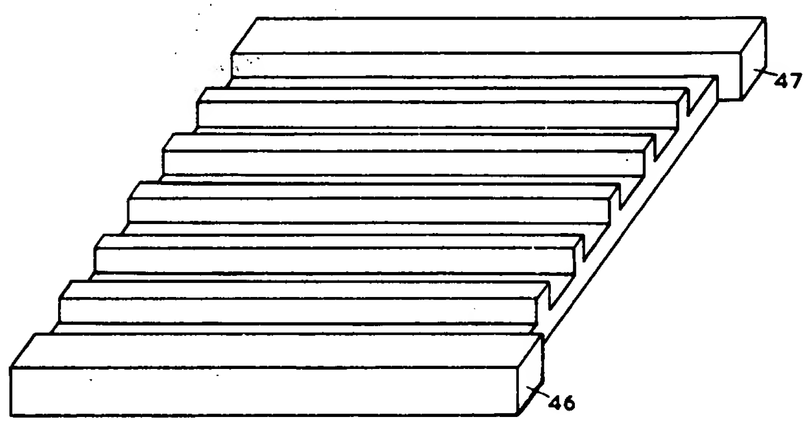

FIG. 10

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PATENT SPECIFICATION

(11) 1 354 502

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(21) Application No. 41603/70 (22) Filed 28 Aug 1970 (19)

(23) Complete Specification filed 4 Aug 1971

(44) Complete Specification published 30 May 1974

(51) International Classification F28F 3/00

(52) Index at acceptance
F4S 4G 4U29

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(54) HEAT EXCHANGERS

(71) We, IMPERIAL CHEMICAL INDUSTRIES LIMITED of Imperial Chemical House, Millbank, London, S.W.1., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to heat exchangers of the type wherein heat is transferred between fluids of differing temperatures through thin walled members. One of the problems associated with heat exchangers of this type is the corrosive action of many fluids on the material from which the heat exchanger is fabricated and also the deposition of scale on the heat transfer surfaces.

It has been proposed to overcome these problems by the use of a large number of small diameter thin wall tubes of polytetrafluoroethylene (PTFE), called "spaghetti tubing", through which one of the fluids passes, the other fluid flowing over the outside of the tubes, (see for example British Patent 1 107 843). Because of the good corrosion resistance of PTFE and its outstanding non-stick properties such tubes are corrosion resistant and also resist scaling.

One of the limitations of "spaghetti tubing" heat exchangers is that only a small pressure differential between the two fluids is permissible or else the tubes are liable to rupture, particularly where the higher pressure fluid is the one passing through the tubes. Another limitation arises from the difficulty of obtaining good sealing of the ends of the tubes to larger bore inlet and outlet pipes at the ends of the heat exchanger. One method which can be used is to embed the ends of the tubes in a potting compound, such as an epoxy resin, which is then used as a plug in the inlet and outlet pipes. However this method suffers from the disadvantage that epoxy resins do not have the same resistance to corrosion as PTFE and so are more liable to be corroded and also it is difficult to obtain pressure tight joins between the epoxy resin and each of the large number of PTFE tubes.

We have now devised an alternative method of heat exchanger manufacture.

Accordingly we provide a heat exchanger comprising a block formed from a plurality of plates of plastics material spaced apart at least over areas intermediate their edges, spacers of plastics material at opposite edges of the plates forming seals between adjacent plates at said edges and defining passages for fluid passing between the spaced apart areas of the plates, wherein the plastics material is selected from fluorocarbon polymers, aromatic polyamides, high density polyethylene or polypropylene. Preferably one set of passages terminates at one pair of faces of the block and another set of passages not communicating with the first set terminates at a different pair of faces of the block.

Where at least one of the fluids passing through the heat exchanger is corrosive or is at a high temperature it is preferred that an aromatic polyimide or a fluorocarbon polymer such as polytetrafluoroethylene polytrifluorochloroethylene, polyvinyl fluoride, copolymers of tetrafluoroethylene and hexafluoropropylene or copolymers of vinylidene fluoride and hexafluoropropylene be used. On the other hand for less severe conditions for example where the heat exchanger is operated using water at moderate temperatures, for example, in desalination plants high density polyethylene or polypropylene may conveniently be used. Additional strength and rigidity may be imparted to these materials by using glass-filled compositions.

For convenience the invention will be de-

scribed with reference to PTFE, although it will be understood that the invention is applicable to heat exchangers made from one of the other plastics materials above mentioned. By the term "PTFE" we include polytetrafluoroethylene and copolymers of tetrafluoroethylene and a minor amount of another monomer such as hexafluoropropylene or ethylene.

The spacers may be integral with the plates being formed for example by moulding or machining, e.g. milling, or by hot coining of sheet or by paste extrusion, or alternatively they may be fabricated as separate parts. It is essential that at opposite edges of each plate good seals are formed between the spacers and the plate above and/or below it. This may be achieved by use of a suitable adhesive e.g. a melt-processable fluoroethylene-propylene (FEP) resin, in which case the PTFE parts are hot pressed with the FEP resin in the bonding positions, the PTFE being either sintered previously or sintered during the hot pressing. Alternatively the PTFE parts may be unsintered and the necessary seals made by sintering the assembly under pressure whereby the spacers and plates are sintered together.

Where materials other than PTFE are used sealing between the edges of each plate may be achieved with an appropriate adhesive. In the case of an aromatie polyimide a solution of a partially cured polyimide may be used. Alternatively, the polyimide parts may be fabricated from a partly cured polyimide moulding powder which may be compacted into the required shapes by any of the techniques used for fabricating PTFE. The necessary seals may then be made by fully curing the polyimide parts and subsequently sintering the parts together. For materials such as polypropylene or high-density polyethylene sintering is inappropriate but adequate sealing may be achieved by using a melt adhesive consisting of a copolymer of an ethylenically unsaturated carboxylic acid or carboxylic acid anhydride grafted onto the appropriate polyolefin.

The invention is illustrated by reference to the accompanying drawings wherein:

Figure 1 is an isometric view of a plate forming part of a heat exchanger;

Figure 2 is an isometric view of an assembled heat exchanger block with a top sheet omitted for clarity;

Figure 3 is a view of the block of Figure 2 when complete;

Figure 4 is a view of another form of completed heat exchanger block;

Figure 5 is a cross section of a heat exchanger showing a preferred mode of connecting the inlet and outlet pipes for the heat exchange media;

Figure 6 is a cross section of another form of plate having integral spacing ribs;

Figure 7 is a cross section of a heat exchanger block showing a multipass system;

Figure 8 is an isometric view of part of the heat exchanger shown in Figure 7, with the exterior cladding partly removed and the connecting adaptors omitted;

Figures 9 and 10 are isometric views of the sheets used to make the heat exchanger of Figures 7 and 8.

Referring to Figures 1 and 2, the heat exchanger block is built up from a series of members in the form of plates or sheets 1 of PTFE, rectangular in plan view, and each having ribs or spacers 2 at one pair of opposite edges. The lateral ribs are integral with a central thin part 1a of the plate which is to conduct heat from one fluid passing through the heat exchanger to another. The thickness of the part 1a and the height of the ribs 2 is exaggerated in the drawings. The ribs 2 serve to space the central parts of the plates from each other and act as sidewalls for flow passages 5, 6 designed to carry the fluids through the block.

The plates have holes 3 bored close to each corner in the intended area of overlap of successive ribs, the holes being in register when the plates are stacked one on top of the other during the assembly of the heat exchanger block.

A top planar plate or sheet of thickness similar to part 1a of the other plates and having corner holes similar to the other plates is added to the arrangement shown in Figure 2 to complete the assembly prior to bonding. A tightly fitting peg 4 of sintered PTFE may then be passed through each set of holes to assist in preventing lateral displacement of the plates during the subsequent pressing operation.

Figure 3 shows the block after pressing, the position of the top plate being shown at 11.

Sintered or unsintered PTFE may be used to make the plates. If sintered material is used, a bonding material is placed between the tops of the ribs 2 and the underside of the next plate and the assembly is hot pressed. A film of FEP resin e.g. a melt-processable tetrafluoroethylene/hexafluoropropylene copolymer may be used or a cord seal of unsintered PTFE extrudate. The temperature used must be sufficient to melt the FEP in the former case and in the latter must be sufficient to sinter the cord seal.

If unsintered material is used, an FEP film or an unsintered cord may still be used, but it is preferred to bond the tops of the ribs to the next plates by sintering the assembly under pressure without any additional sealing means. Sintering at 380°

for 3 hours under a pressure of 0.5 kg to 2.5 kg/sq cm has been found suitable for small blocks.

As an alternative to the use of the pegs 4, the plates may be assembled within a closely fitting box and hot pressing effected within the box.

However the bonding is done, it is essential that a seal which is tight against leaking of the desired fluid at the temperature to be used is obtained between the ribs along the whole of their lengths and the overlying plate.

It will be noted that the ribs of successive plates run perpendicularly to each other so that two sets of flow passages 5, 6 are formed at right angles. Passages 5 intended to carry one fluid terminate at a pair of opposite faces 9, 10 of the block and passages 6 intended to carry a different fluid terminate at a different pair of faces 7, 8.

Figure 4 shows another form of completed heat exchanger block which has been built up from a series of ribbed plates 13 and a planar top plate which have been sealed together.

The plates 13 are generally similar to those shown in Figure 2 with the difference that the lateral ribs 12 are narrower and an intermediate rib 11 integral with the plate is provided equidistant from and parallel to the ribs 12. Preferably the plates 13 are made by moulding unsintered PTFE and bonding of the assembly is effected by sintering under pressure, but the other means of making plates and bonding previously described may be used. A fluid-tight seal between the lateral ribs 12 and the overlying plates along the whole of the lengths of the ribs is essential though continuous bonding along the intermediate ribs is not essential, though is preferred.

The intermediate ribs 11 divide the flow passages 14, 15 between successive plates 13 into two. The ribs 11 serve to support the plates intermediate the edges and so help to prevent distortion during bonding and subsequently during use. This is of importance especially in ensuring a good seal between the upper surfaces of the lateral ribs and the next plate above. The intermediate ribs at their ends, together with the other plates in the stack provide a continuous column of material midway along each edge of the unit allowing transmission of pressure throughout the block and so assisting good contact during application of pressure between the lateral ribs and plates. More than one intermediate rib may be provided if desired, as shown at 47 in Figure 6.

The overlapping parts of the lateral ribs 2 in Figure 2 and 12 in Figure 4 also provide with the other plates pressure transmitting columns through the block.

As an alternative to plates having integral spacers, a heat exchanger block may be built up from a plurality of planar PTFE sheets with interposed spacers fabricated as separate parts. Fluid tight bonding must in the case of lateral spacers be effected between the spacer and the sheet above and below it. In the case of intermediate spacers, if any, fluid tight bonding is not essential but bonding or mechanical interlock (e.g. by locating the intermediate spacer in a recess in the sheet) must be adequate to keep the spacer in position. Bonding may be carried out by one of the methods previously discussed.

The general arrangement of a completed block may be similar to that shown in Figure 3 or 4 but variations may obviously be selected not only when the spacers are separately fabricated but also when they are integral with one sheet.

After constructing the heat exchanger block and carrying out any necessary trimming and smoothing operations to the faces of the block, it may be connected to inlet and outlet adaptors. This is illustrated in Figure 5 for a block of the type shown in Figure 4. Each adaptor covers all the ports on one face of the rectangular heat exchanger block.

Thus in Figure 5, adaptors 29 and 30 may be connected respectively to an inlet pipe and an outlet pipe (not shown). One of the fluids to be passed through the heat exchanger is fed to adapter 29 from whence it passes through one set of flow passages e.g. 14 in the heat exchanger and out, via adaptor 18 to the outlet pipe. The other fluid passing through the heat exchanger flows from another inlet pipe (not shown), via adaptor 31, through the flow passages e.g. 15 perpendicular to the other set of passages, to an outlet pipe (not shown) via adaptor 27. All the pipes serving the heat exchanger may be made from PTFE.

In Figure 5 bell shaped adaptors 29, 30, 31, 32 which have PTFE linings 33 and peripheral flanges 34 are clamped against the faces 35, 36, 37, 38 of the block. PTFE gaskets 39 are interposed between the flanges 34 and the faces of the block. The adaptors 29, 30 are clamped against the faces 35, 36 by means of bolts 40 extending between extensions 41 of flanges 34 of adaptors 29, 30 while adaptors 31, 32 are clamped against the faces 37, 38 by means of bolts 42 extending between extensions 43 of flanges 34 of adaptors 31 and 32.

The heat exchanger may be constructed as a single pass or multipass system for either or both of the heat exchange fluids.

In a multipass system, the heat exchange fluid being multipassed, after passing between one pair of sheets of the heat exchanger is then passed between a second pair of sheets of the heat exchanger. Such a system is shown in Figures 7 and 8.

The heat exchanger block is made, with the exception of an outside cladding, out of a stack of sheets alternatively of the type shown in Figures 9 and 10. These sheets have a ribbed cross section of the type shown in Figure 6 and a cut away portion. In the sheet shown in Figure 9 the cut away portion is a longitudinal recess 44 in one of the edge spacers 45. In the sheet shown in Figure 10, a portion between the edge spacers 46, 47 is cut away at one side of the sheet.

The lowermost sheet 48 of the heat exchanger block is of the configuration shown in Figure 10 with the cut away portion at the right hand side referring to Figure 7. Above this sheet 48 is stacked a sheet 49 of the configuration shown in Figure 9, rotated through 180° so that the cut away portion 44 is at the left hand side and the ribs extending in a direction at right angles to the ribs of sheet 48.

Above sheet 49 is another sheet 50 of the configuration shown in Figure 10, rotated through 180° so that the cut away portion lies immediately above the cut away portion 44 of sheet 49.

Above sheet 50 is a sheet 51 of the configuration shown in Figure 9 with the cut away portion 44 at the right hand side. A sheet 52 of the configuration shown in Figure 10 is stacked above sheet 51 with the cut away portion immediately above the cut away portion 44 of sheet 51.

This mode of assembly is continued, ending with a sheet 53 of the configuration shown in Figure 10. Above the sheet is plain sheet 54 serving to enclose the channels between the ribs of sheet 53. After bonding sheets 48 to 54, further plain sheets 55, 56 are bonded to the end faces of the assembled block.

An outlet adaptor 57 is clamped against sheet 56 communicating with the channels between the ribs of sheet 53 via a port in sheet 56. For ease of clamping adaptor 57 to the block, a longitudinal block 58 is bonded to the outer surface of sheet 54.

Similarly an inlet adaptor 59 is clamped against sheet 55 and communicates, via a port in sheet 55, with the channels between the ribs of sheet 48. Again for ease of clamping a block 60 is bonded to sheet 48 but in this case the block 60 has a longitudinal protuberance 61 which engages with the lower part of the cut out in sheet 48.

In an alternative form, sheet 48 may have no cut away portion and so the protuberance 61 on block 60 may be omitted.

The adaptors for connecting the transverse channels, e.g. between the ribs of sheets 49 and 51, for the flow of the other heat exchange medium, to inlet and outlet ports are not shown.

In this system, one heat exchange medium (that flowing transversely e.g. between the ribs of sheets 49 and 51) is single passed, i.e. it only flows through the block once, while the other heat exchange medium (that flowing into the inlet 59) is multipassed i.e. it flows in a zig-zag fashion through the block as indicated by the arrows in Figure 7, e.g. flowing from the channels between the ribs of sheet 48 to the channels between the ribs of sheet 50 via the cut out portions in sheets 49 and 50.

It will be appreciated that by arranging a similar by-pass system for the other heat exchange medium, both heat exchange media may be multipassed if desired.

In all the above embodiments, the parts of the sheets or plates intended to pass heat should be thin enough to permit adequate heat transfer. Preferably the sheet thickness in these areas is 0.01 — 1.0 mm, particularly 0.025 — 0.5 mm. Such sheets when planar may be made, inter alia, by skiving from a rotating cylinder.

The thermal conductivity of the sheet can be increased by incorporating a filler into the fluorocarbon composition. For best corrosion resistance, carbon is the preferred filler.

While carbon filled PTFE sheets can be made by skiving, another convenient method is by impregnation of a carbonaceous sheet, e.g. paper with a PTFE dispersion followed by sintering during which the carbonaceous sheet is charred to carbon. This process is described in our United Kingdom Patent Specification 1 163 423. When using such materials, the fluid pressure on each side of the sheets should be the same.

The thickness of the spacers is not critical. They should be thick enough to permit the desired flow of fluid through the heat exchanger but on the other hand, since essentially only the surface layer of the fluid in contact with the sheets is subjected to heat exchange, the flow passages, and hence the spacers, should be maintained relatively thin so that the heat transfer is efficient. Spacer thicknesses (i.e. height above the heat transmitting parts of the sheets) in the range 0.05 — 1.0 mm are particularly suitable.

The central spacers, e.g. spacers 11 and 47 in Figures 4 and 6 respectively, give added strength to the heat exchanger structure and tend to prevent collapse of flow

passages, particularly where one fluid is supplied to the flow passages under a higher pressure than the other. In some cases it may be necessary to provide more intermediate spacers than one central one or in other cases the central or intermediate spacers may be omitted.

WHAT WE CLAIM IS:—

1. A heat exchanger comprising a block formed from a plurality of plates of plastics material spaced apart at least over areas intermediate their edges, spacers of plastics material at opposite edges of the plates forming seals between adjacent plates at said edges and defining passages for fluid passing between the spaced-apart areas of the plates, wherein the plastics material is selected from fluorocarbon polymers, aromatic polyamides, high density polyethylene or polypropylene.

2. A heat exchanger according to claim 1 wherein one set of passages terminates at one pair of faces of the block and another set of passages not communicating with the first set terminates at a different pair of faces of the block.

3. A heat exchanger according to claim 1 or 2 wherein each of the spacers is formed integrally with a plate and is made to form a seal with an adjacent plate-like member on assembly of the block.

4. A heat exchanger according to claim 3 wherein the spacers are formed only at a pair of opposite edges of the plate.

5. A heat exchanger according to claim 3 wherein the spacers are formed at a pair of opposite edges of the plate and also intermediate the edges so as to define two or more channels.

6. A heat exchanger according to claim 1 or 2 wherein the spacers are fabricated as separate parts and are sealed to adjacent plates on assembly of the block.

7. A heat exchanger according to any one of the preceding claims in the form of a rectangular block with fluid flow passages on opposite sides of plates within the block directed at right angles to each other.

8. A heat exchanger according to any one of the preceding claims in which the plastics material is selected from polytetrafluoroethylene, polytrifluorochloroethylene, polyvinyl fluoride, copolymers of tetrafluoroethylene with minor amounts of other copolymerisable monomers, copolymers of vinylidene fluoride and hexafluoropropylene.

9. A heat exchanger according to any one of the preceding claims in which the plastics material is polytetrafluoroethylene or a copolymer of tetrafluoroethylene with a minor amount of another copolymerisable monomer.

10. A heat exchanger according to claim 9 wherein the spacers are sealed to adjoining plates by means of a tetrafluoroethylene/hexafluoropropylene copolymer.

11. A heat exchanger according to claim 9 wherein the spacers are sealed to adjoining plates by the action of sintering under pressure.

12. A heat exchanger according to claim 1 substantially as herein described with reference to the accompanying drawings.

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Agent for the Applicants.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1974
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.